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Pesticide workers usually contaminate their cigarettes with less than 100 μg per cigarette by handling them, but in some instances such contamination has been found to be over 200 μg. To obtain values for potential exposure resulting from smoking contaminated filter tip and non-fileter cigarettes, from 10 to 200 μg of parathion was applied to the cigarette surface are found to be most often contaminated by hands. This was followed in two separate experiments by simulated smoking using a special apparatus to determine (1) passage of toxic material through cigarettes in mainstream smoke, (2) amount found in sidestream smoke, (3) amount trapped in the filter or equivalent butt end, and (4) amount recovered in ashes. The amount of parathion passing through cigarettes as a potential for inhalation exposure ranged up to 28% of dosing levels. No paraoxon or S-ethyl parathion was detected. Although there was an indication that slightly more pesticide was recovered from filters than from equivalent butt ends, the amount recovered in mainstream smoke of filter type cigarettes was not significantly lower than for nonfilter cigarettes. Location of contamination on a cigarette had minimal effect on the amount found in mainstream smoke.

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# Potential Exposure From Smoking Parathion-Contaminated Cigarettes

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**Abstract.** Pesticide workers usually contaminate their cigarettes with less than 100 μg per cigarette by handling them, but in some instances such contamination has been found to be over 200 μg. To obtain values for potential exposure resulting from smoking contaminated filter tip and nonfilter cigarettes, from 10 to 200 μg of parathion was applied to the cigarette surface area found to be most often contamined by hands. This was followed in two separate experiments by simulated smoking using a special apparatus to determine (1) passage of toxic material through cigarettes in mainstream smoke, (2) amount found in sidestream smoke, (3) amount trapped in the filter or equivalent butt end, and (4) amount recovered in ashes. The amount of parathion passing through cigarettes as a potential for inhalation exposure ranged up to 28% of dosing levels. No paraoxon or *S*-ethyl parathion was detected. Although there was an indication that slightly more pesticide was recovered from filters than from equivalent butt ends, the amount recovered in mainstream smoke of filter type cigarettes was not significantly lower than for nonfilter cigarettes. Location of contamination on a cigarette had minimal effect on the amount found in mainstream smoke.

Workers often smoke cigarettes while handling or applying toxic pesticides without regard as to whether or not the cigarettes have become contaminated. In an earlier publication (Wolfe *et al.* 1975) we reported studies on potential parathion contamination of cigarettes by spray drift and by contact with pesticide-contaminated hands. In most cases contamination values were found to be below 100 μg per cigarette as a result of normal handling while smoking one-half a cigarette during normal spray application operations; however, where hands had been in contact with the more concentrated formulations of parathion the values ranged to over 200 μg per cigarette. Although the study provided some information as far as potential contamination is concerned, it did not include studies designed to determine the amount of parathion or its breakdown products which might pass through a cigarette during smoking, and thus be available for inhalation.

The purpose of the present study was to determine the amount of parathion and its toxic products, paraoxon and *S*-ethyl parathion, that might pass through a cigarette during smoking.

## Materials and Methods

In an attempt to explore the fate of parathion in burning cigarettes during simulated smoking, two procedures were employed as follows:

### *Procedure I*

A popular brand of filter tip and nonfilter cigarette (to be referred to as Brand A) was utilized in a series of tests to determine the fate of parathion during simulated smoking. This brand was felt to be suitable for comparing filter with nonfilter types because both types of this brand were 85 mm in total length. The test cigarettes were experimentally contaminated by application of parathion to the surface at a point midway between the forward end and the filter (or equivalent butt length for the nonfilter type). Application was by microliter syringe using a standard solution of parathion (11 $\mu g/\mu l$) to produce a spot containing 110 $\mu g$ of parathion. Each drop was allowed to dry before the next one was applied in order to confine the zone of spread of contaminant to an area approximately 3 mm in diameter. The amount that actually penetrated the paper into the tobacco was not determined; however, it was apparent that moisture from the solution did reach the tobacco. The topical "spot" application technique was employed in order to simulate contamination by workers who handle cigarettes while their hands are moist with spray solution. In this procedure smoke and/or pesticide from test cigarettes was collected with an apparatus that held a cigarette in a fixed horizontal position, and simulated smoking "puffs" were accomplished with a controlled vacuum and equipment as described below. Immediately after a cigarette was lit a glass "hood" was placed over it to collect sidestream smoke. After a 30-sec free burn, a puff of 2-sec duration was drawn once every min using a vacuum obtained by allowing a measured volume (35 ml) of water to run out of a separatory funnel. This separatory funnel was connected to the cigarette holder with a column containing Florisil. The cycle was repeated until the cigarette was burned down to a 30-mm butt or to the filter tip. Seven cycles were required to burn the cigarette to that length. The 35-ml puff of 2-sec duration once each min has become standard practice in research (Ogg 1964, Harlow 1956, Hobbs 1972, Atallah and Dorough 1975). While the cigarette was being "smoked" an aspirator connected to the "hood" and two Florisil traps connected in series were operated at a flow sufficient to pull all of the sidestream smoke from the free burn periods (58 sec each cycle) through the traps. At the completion of the "smoking" operation the hood was removed and, using forceps, the butt was removed from the holder and placed in a 3.61-ml bottle which was immediately capped. After the butt was extinguished (usually within 5 sec following capping of the bottle) a measured volume of 95% ethanol was added to the bottle and the sample stored pending analysis.

The samples obtained in this procedure were analyzed with a Varian Aerograph gas chromatograph, Model 1527-C, equipped with a 230 mc tritium electron capture detector utilizing a 1.83 m × 0.31 cm stainless steel column packed with 4% SE-30/6% QF-1 on 80/100 mesh Varoport 30. The identity of the parathion was confirmed on a Microtek MT-220 gas chromatograph equipped with a Melpar flame photometric detection system, in the phosphorus mode of operation, utilizing a 1.83 m × 0.63 cm glass column packed with 1.5% OV-17/1.95% QF-1 on Chromosorb W, HP, 100/120 mesh.

### *Procedure II*

Another series of tests was carried out using two brands of cigarettes—one a 100-mm length filter tip cigarette (Brand B) and the other included both filter and nonfilter types of a popular brand (Brand C). The two types of Brand C cigarettes were slightly different in length, thus, in order to make a more accurate comparison between these filter tip and nonfilter cigarettes, the forward end of the filter tip was cut off so that its total length was equivalent to the 85-mm length of the nonfilter type.

The test cigarettes were contaminated on the surface with a solution of 1 $\mu g$ of parathion per 1 $\mu l$ of 2,2,4-trimethylpentane. Dosages used were 10, 50, 100, and 200 $\mu g$ of parathion per cigarette, applied by syringe in strips along the cigarette surface from the filter (or equivalent butt length for

nonfilter cigarettes) to a point approximately 5 mm from the forward end of the cigarette. At the 100 and 200 μg dosages most of the surface area around the circumference of the cigarette was contaminated. The amount of pesticide that penetrated the cigarette paper into the tobacco was not determined.

In this procedure the "smoking" apparatus used was much simpler than that used in Procedure I, the only trap for mainstream smoke being a single glass column containing 2 g of Florisil. Sidestream smoke was not collected. Vacuum for drawing smoke through the cigarettes was provided by connecting the column to a water aspirator. In one series of tests the cigarettes were "smoked" by a continuous low vacuum to produce a slow burn which consumed a cigarette without interruption in from 4 to 6 min. This technique was carried out with cigarettes in a vertical position with burning end up and also in a horizontal position. Tests were also carried out with cigarettes held in a horizontal position with the column intermittently connected to the water aspirator to draw a 20-ml puff of 2-sec duration once every min. Approximately 9 min, involving 9 puffs, were required to consume a cigarette to the filter or equivalent butt.

In another series of tests using the simulated smoking "puff technique," filter tip cigarettes held in a horizontal position were "spot-contaminated" with 100 μg of parathion at one of three locations: (1) near the burning end, (2) near the filter, or (3) midway between these two locations. As in Procedure I, a more concentrated solution was used in order to confine the spread of contaminant to an area approximately 3 mm in diameter. The amount of parathion or breakdown products trapped in the filters and the amount in the mainstream smoke passing through the cigarettes was determined.

After the test cigarettes in Procedure II were "smoked" the cigarette filters or nonsmoked butts were placed in 15-ml centrifuge tubes and extracted with ethanol by tumbling the tubes slowly for 5 min. Also, 95% ethanol was used to elute the parathion from the Florisil columns. The levels of parathion in the column effluent (representing potential inspired smoke) and in the filter extract (representing potentially noninspired smoke) were measured by using gas liquid chromatography.

A Microtek MT-220 gas chromatograph equipped with a Melpar flame photometric detector was used. Glass columns, 1.83 m × 0.63 cm packed with 5% Apiezon L on Gas Chrom Q, 80/100 mesh, and 4% SE-30/6% QF-1 on Chromosorb W, HP, 80/100 mesh were employed.

During certain tests, in an effort to determine whether or not any parathion was lost by passage through a Florisil column, a battery-operated portable vacuum pump, drawing 2.83 L of air per min through midget impingers containing ethanol, was connected to the effluent end of the Florisil column with polyethylene tubing.

Cigarette ashes were placed in test tubes containing ethanol pending analyses for parathion residues.

## Results and Discussion

The results of the experiment to determine passage of parathion and/or breakdown products through contaminated cigarettes during simulated smoking are shown in Tables 1 through 6. The tests shown in Table 1 were carried out by using Procedure I where 110 μg of parathion was applied midway on the cigarettes, and 2-sec puffs were employed while the cigarettes were held in a horizontal position. After checking the smoke, filter, and ash residues, only about one-half of the 110 μg was accounted for. Some of the parathion was probably destroyed by combustion in the process. A significantly greater amount of parathion was found in the sidestream smoke (32.2%) than in the mainstream smoke (15.3%). Although there was an indication that slightly more pesticide was recovered from filters than from equivalent butt ends, the amount recovered in mainstream smoke of filter type cigarettes was not significantly lower than for nonfilter cigarettes.

**Table 1.** Recovery of parathion from cigarettes during simulated smoking following contamination with 110 μg parathion p cigarette[a]

| Brand A filter tip | | | | | Brand A nonfilter tip | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Mean recovered | | | | | Mean recovered | |
| No. tests | Recovery source | Range of μg recovered | μg | % | No. tests | Recovery source | Range of μg recovered | μg | % |
| 19 | Sidestream smoke | 22.6–46.3 | 36.4 | 33.1 | 20 | Sidestream smoke | 20.4–52.0 | 36.1 | 32.8 |
| 20 | Filter | 2.1–15.8 | 6.4 | 5.8 | 20 | Unsmoked butt end | 0.5– 3.8 | 2.0 | 1.8 |
| 19 | Mainstream smoke | 10.6–24.9 | 16.8 | 15.3 | 19 | Mainstream smoke | 10.2–22.8 | 16.4 | 14.9 |
| 20 | Ash | el[b]– 0.4 | <0.01 | <0.01 | 20 | Ash | el[b]–0.1 | <0.01 | <0.0 |

[a] Surface (single spot application) contamination located midway between forward end and filter or equivalent butt. Cigarett held in *horizontal* position. *Puff technique*
[b] Below lower limit of sensitivity of method

Table 2 shows the results, using Procedure II, whereby different levels of parathion were applied by streaking the contaminant solution along the cigarette surfaces. The cigarettes were held in the horizontal position and the "puff technique" was employed. In this experiment, involving king-size filter tip cigarettes, the results indicate that when from 10 to 200 μg of parathion was applied, the average values for the amount of parathion recovered from the mainstream smoke ranged from 0.6 to 8.5 μg. This is 4.3 to 6% of the amounts

**Table 2.** Recovery of parathion from cigarettes during simulated smoking following contamination with different levels of pesticide per cigarette[a]

| | | Brand B filter tip | | | |
|---|---|---|---|---|---|
| | | μg Recovered[b] | | Mean total recovered | |
| Contamination (μg) | | Mainstream smoke | Trapped in filter | μg | % |
| 10 | Range | 0.4– 1.0 | 0.3– 1.2 | | |
| | Mean | 0.6 | 0.7 | 1.3 | 13.0 |
| 50 | Range | 2.1– 3.8 | 2.2– 3.3 | | |
| | Mean | 2.8 | 2.7 | 5.5 | 11.0 |
| 100 | Range | 3.8– 6.8 | 4.6–11.5 | | |
| | Mean | 4.9 | 6.9 | 11.8 | 11.8 |
| 200 | Range | 7.2–10.8 | 7.1–16.8 | | |
| | Mean | 8.5 | 10.4 | 18.9 | 9.5 |

[a] Surface (strip application) contamination spread between forward end and filter. Cigarettes held in *horizontal* position. *Puff technique.*
[b] 10 replicates of each test

applied. At the 100 μg contamination level there was less parathion recovered from the mainstream smoke than in the previous test. The use of different techniques as well as different sizes and brands of cigarettes may account for some of the difference.

Tables 3 and 4 show the results, using Procedure II, for two series of tests using a constant draw (low vacuum), with the cigarettes in a vertical or a horizontal position. The pesticide solution was applied in streaks along the surface of the cigarette. The data in the tables do not indicate much difference due to the attitude of the cigarette, in the amount of pesticide drawn through it, when a constant draw was employed.

Table 5 shows results using the same brand of cigarettes which also had parathion streaked along their surfaces; however, in this case the "puff technique" tests, Procedure II, were employed. It should be noted that when the "puff technique" was employed less parathion was recovered from the mainstream smoke than when a constant draw was used (Table 4). This is to be expected since constant draw results in trapping sidestream as well as mainstream smoke. However, the "puff technique" is probably more representative of actual smoking conditions.

Data in Table 6 indicate that, under the conditions of this experiment ("puff technique," Procedure II), location of contamination on the cigarette had minimal effect on the amount found in the mainstream smoke, with slightly higher values obtained when the pesticide was placed near the burning end.

Table 3. Recovery of parathion from cigarettes during simulated smoking following contamination with different levels of pesticide per cigarette[a]

| Contamination (μg) | | Brand C filter tip[b] | | | | Brand C nonfilter tip | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | μg Recovered[c] | | Mean total recovered | | μg Recovered[c] | | Mean total recovered | |
| | | Mainstream smoke | Trapped in filter | μg | % | Mainstream smoke | Trapped in butt | μg | % |
| 10 | Range | <0.2– 1.8 | 1.3– 2.2 | | | 0.8– 1.8 | 0.2– 0.6 | | |
| | Mean | <1.3 | 1.7 | 3.0 | 30.0 | 1.1 | 0.4 | 1.5 | 15.0 |
| 50 | Range | 3.0– 9.4 | 3.3–10.9 | | | 6.4–12.4 | 1.7– 3.2 | | |
| | Mean | 7.6 | 8.7 | 16.3 | 32.6 | 8.7 | 2.3 | 11.0 | 22.0 |
| 100 | Range | 13.4–28.2 | 21.2–27.2 | | | 14.2–36.8 | 4.4– 7.6 | | |
| | Mean | 19.8 | 24.3 | 44.1 | 44.1 | 23.6 | 6.2 | 29.8 | 29.8 |
| 200 | Range | 19.2–39.2 | 36.0–54.5 | | | 28.5–54.0 | 9.0–16.3 | | |
| | Mean | 30.4 | 46.4 | 76.8 | 38.4 | 41.9 | 11.7 | 53.6 | 26.8 |

[a] Surface (strip application) contamination spread between forward end and filter or equivalent butt. Cigarettes held in *vertical* position. *Constant draw*

[b] Cut to same length of nonfilter tip cigarette

[c] 10 replicates of each test

**Table 4.** Recovery of parathion from cigarettes during simulated smoking following contamination with different levels of pesticide per cigarette[a]

| Contamination (μg) | | Brand C filter tip[b] | | | | Brand C nonfilter tip | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | μg Recovered[c] | | Mean total recovered | | μg Recovered[c] | | Mean total recovered | |
| | | Mainstream smoke | Trapped in filter | μg | % | Mainstream smoke | Trapped in butt | μg | % |
| 10 | Range | 1.0– 1.4 | 0.8– 1.2 | | | 1.7– 2.3 | 0.4– 0.6 | | |
| | Mean | 1.2 | 1.0 | 2.0 | 20.0 | 2.1 | 0.5 | 2.6 | 26.0 |
| 50 | Range | 2.9– 9.5 | 7.0–15.3 | | | 7.2–17.4 | 2.0– 3.1 | | |
| | Mean | 6.7 | 11.7 | 18.4 | 36.8 | 12.8 | 2.6 | 15.4 | 30.8 |
| 100 | Range | 11.0–28.5 | 17.0–35.2 | | | 20.2–34.9 | 6.4–11.3 | | |
| | Mean | 17.2 | 27.4 | 44.5 | 44.5 | 28.0 | 8.7 | 36.7 | 36.7 |

[a] Surface (strip application) spread between forward end and filter or equivalent butt. Cigarettes held in *horizontal* position. *Constant draw*
[b] Cut to same length of nonfilter tip cigarette.
[c] 10 replicates of each test

**Table 5.** Recovery of parathion from cigarettes during simulated smoking following contamination with different levels of pesticide per cigarette[a]

| Contamination (μg) | | Brand C filter tip[b] | | | | Brand C nonfilter tip | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | μg Recovered[c] | | Mean total recovered | | μg Recovered[c] | | Mean total recovered | |
| | | Mainstream smoke | Trapped in filter | μg | % | Mainstream smoke | Trapped in butt | μg | % |
| 10 | Range | 0.4– 0.5 | 0.4– 0.6 | | | 0.4– 0.8 | 0.3–0.4 | | |
| | Mean | 0.5 | 0.5 | 1.0 | 10.0 | 0.6 | 0.3 | 0.9 | 9.0 |
| 50 | Range | 2.2– 3.2 | 2.2– 2.9 | | | 3.0– 5.0 | 1.1–2.0 | | |
| | Mean | 2.7 | 2.6 | 5.3 | 11.0 | 4.0 | 1.4 | 5.4 | 11.0 |
| 100 | Range | 5.4– 6.8 | 6.6– 7.2 | | | 5.5– 9.7 | 2.2–5.1 | | |
| | Mean | 5.9 | 7.1 | 13.0 | 13.0 | 7.5 | 3.5 | 11.0 | 11.0 |
| 200 | Range | 8.7–15.5 | 4.7–18.0 | | | 10.8–17.2 | 2.4–5.8 | | |
| | Mean | 12.1 | 12.1 | 24.2 | 12.0 | 12.8 | 4.5 | 17.3 | 8.7 |

[a] Surface (strip application) contamination spread between forward end and filter or equivalent butt. Cigarettes held in *horizontal* position. *Puff technique*
[b] Cut to same length of nonfilter tip cigarette
[c] 10 replicates of each test

**Table 6.** Recovery of parathion from cigarettes during simulated smoking following contamination with 100 μg parathion at different locations on cigarettes[a]

| | | Brand B filter tip | | |
|---|---|---|---|---|
| | | μg Recovered[b] | | Mean total recovered |
| Contamination location | | Mainstream smoke | Trapped in filter | μg or % |
| Near filter | Range | 1.0– 5.9 | 1.0–9.4 | |
| | Mean | 2.6 | 3.8 | 6.4 |
| In middle | Range | 1.0– 4.2 | 1.0–4.9 | |
| | Mean | 2.4 | 2.8 | 5.2 |
| Near lit end | Range | 2.0–11.3 | 2.0–8.5 | |
| | Mean | 5.8 | 4.6 | 10.4 |

[a] Surface (single spot application) contamination. Cigarettes held in *horizontal* position. *Puff technique*

[b] 10 replicates of each test

Of particular interest in all of the cigarette studies is the fact that there was no evidence of the formation of the more toxic oxidation product paraoxon, or the *S*-ethyl isomer of parathion. Paraoxon and *S*-ethyl parathion should have been detected if 40 and 80 ng, respectively, had been present in any of the analyzed fractions (10 ml of extract). This corresponds to 0.02 and 0.04%, respectively, of the parathion applied at the highest concentration (200 μg/cigarette). No parathion or its conversion products were detected in untreated control cigarettes.

Values for the amounts of the parent compound available for inhalation as mainstream smoke passing through the cigarettes were not particularly high. If a pack of 20 cigarettes is smoked under conditions that lead to the single greatest mainstream smoke value obtained in the experiment (54.0 μg per cigarette, using constant draw technique) the amount available as exposure through the respiratory route would be 1.1 mg per pack. Using the formula of Durham and Wolfe (1962) for calculation of percent of toxic dose received, this would amount to approximately 1.2% of a toxic dose per package of cigarettes. If a more realistic contamination value of 100 μg per cigarette using the "puff technique" is used, the highest value in mainstream smoke found was 6.8 μg per cigarette, or 0.1 mg per pack. This would amount to approximately 0.15% of a toxic dose per pack of cigarettes. Even though the values obtained for potential exposure to the parent compound during simulated smoking appear to be relatively low, an important point to consider is that pesticide entering by the respiratory route is practically 100% absorbed. Another important consideration is that such exposure is additive to a possible relatively high dermal exposure of the worker. Thus, a very important recommendation for pesticide applicators, and for workers whose hands come in contact with parathion residues on crop foliage, should be to protect their hands from exposure as much as possible and to wash hands before smoking.

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